PHYSICS & ASTRONOMY

Faculty

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Physics is the fundamental science of the natural world. The study of physics and astronomy leads to a deeper appreciation and awareness of the world around us. From the quantum mechanical behavior at the smallest scale, to the workings of the cosmos at the largest scale, physics consists of a few general principles that explain a vast range of phenomena. Coursework in physics leads to an understanding of these phenomena and gives students experience in abstract mathematical modeling as well as experimental and computational techniques. As a means to enhance the physics curriculum, research opportunities in astronomy and physics are available and strongly encouraged.

A physics major is an appropriate first step on the path to a career as a research scientist. Because physics is such a fundamental science, it can be the basis for the understanding of principles that are relevant to a wide variety of fields. It provides preparation for graduate study in physics or in related fields, such as astrophysics, biophysics, medical physics, chemical physics, geophysics or engineering. A fundamental understanding of nature has been a goal throughout history, and a study of physics can be the focus of a liberal education because of its connections with intellectual history and philosophy. A major in physics can be the platform for pursuing a wide variety of careers, including medicine, law, business and teaching.

A major in physics may be pursued under the bachelor of arts or bachelor of science degree programs, either of which can provide adequate preparation for graduate study. Students in the bachelor of arts program who plan to attend graduate school in physics or astronomy should consult with their advisers to select an appropriate set of electives. The department also offers an astrophysics concentration as an option in both the physics bachelor of arts and bachelor of science degree programs and a distinct bachelor of science degree program with a major in biophysics for students with particular interest in these areas of physics. The standard entry point for all degree programs is the yearlong introductory sequence PHYS 211/PHYS 212.

Modern astrophysics involves the application of physics toward understanding the workings of the universe. Students interested in an introductory survey are encouraged to enroll in ASTR 101 or ASTR 102. Students interested in the astrophysics concentration of the physics bachelor of arts or bachelor of science degree programs can obtain a strong grounding in fundamental physics with specialized coursework in ASTR 201 and ASTR 301 (cross-listed as PHYS 301). This concentration is primarily designed for students considering advanced study in astrophysics or careers in astronomy and related fields.

Biophysics is an interdisciplinary field that applies the theories and methods of physics to problems in biology, medicine and related fields. Biophysics is a vibrant, growing field driven by the large amount of detailed data now available in 21st century biological research. Biophysicists are uniquely trained in the quantitative sciences of physics, mathematics and chemistry to process these data and build models to describe a wide array of topics, from cell signaling to photosynthesis to how cells are transformed from healthy to cancerous.

The biophysics major is highly interdisciplinary resulting in a strong foundation in physics, biology, chemistry and mathematics. Students will develop skills in laboratory techniques, computer programming, data analysis and mathematical modeling. The subject matter ranges from the fundamental principles of physics to chemical reactions and processes to complex biological systems. This broad curriculum provides students majoring in biophysics with opportunities for careers in biotechnology, biomedical technology, medicine and medical physics. The biophysics major also provides a solid grounding for pursuing a Ph.D. in biophysics or related fields.

The Department of Physics & Astronomy encourages students to participate in research projects. Research serves as an important complement to the classroom study of physics and astronomy. The department offers research opportunities in atomic and molecular physics, chaos and nonlinear dynamics, astronomy and astrophysics, theoretical quantum optics, laser spectroscopy, nuclear physics, biophysics, condensed matter theory and computer simulation, and statistical physics.

Bachelor of Arts in Physics

A **Bachelor of Arts major** in physics consists of:

PHYS 211	Classical and Modern Physics I	1
PHYS 212	Classical and Modern Physics II	1
PHYS 221	Classical Mechanics	1
PHYS 222	Wave Mechanics and Quantum Physics	1
PHYS 310	Experimental Physics	1
A minimum of three other 200 or 300-level physics courses, two of which must be at the 300 level.		3

One of the 300-level courses must be one of the following:	
PHYS 317	Thermodynamics and Statistical Mechanics
PHYS 331	Advanced Classical Mechanics
PHYS 332	Quantum Mechanics
PHYS 333	Electromagnetic Theory I
Other courses may include:	
ASTR 201	Observational Astrophysics
ASTR 301	Astrophysics

Bachelor of Arts in Physics with a Concentration in Astrophysics

To complete a Bachelor of Arts major in physics with a concentration in astrophysics the electives must include ASTR 201 Observational Astrophysics and ASTR 301 Astrophysics. In addition to the required coursework, students pursuing a concentration in astrophysics will be advised to participate in one or more on-campus or off-campus research experiences in astronomy or astrophysics. Such opportunities are frequently offered by department faculty as well as through a number of research programs for undergraduates that are hosted at observatories, research institutes and other universities across the country.

Bachelor of Science in Physics

A **Bachelor of Science major** in physics consists of:

PHYS 211	Classical and Modern Physics I	1
PHYS 212	Classical and Modern Physics II	1
PHYS 221	Classical Mechanics	1
PHYS 222	Wave Mechanics and Quantum Physics	1
PHYS 235	Applied Electronics	1
PHYS 310	Experimental Physics	1
PHYS 317	Thermodynamics and Statistical Mechanics	1
PHYS 331	Advanced Classical Mechanics	1
PHYS 332	Quantum Mechanics	1
PHYS 333	Electromagnetic Theory I	1
A minimum of two other 300-level physics credits [1]		2
MATH 212	Differential Equations	1
or MATH 245	Linear Algebra	

[1] These courses may include ASTR 301 Astrophysics.

The recommended course sequence for students pursuing the **Bachelor of Science in Physics** major is the following:

First Year			
First Semester	**Credits**	**Second Semester**	**Credits**
PHYS 211	1	PHYS 212	1
MATH 201	1	MATH 202	1
	2		**2**
Sophomore			
First Semester	**Credits**	**Second Semester**	**Credits**
PHYS 221	1	PHYS 222	1
MATH 211	1	PHYS 235	1
		MATH 212 or 245	1
	2		**3**
Junior			
First Semester	**Credits**	**Second Semester**	**Credits**
PHYS 332	1	PHYS 310	1
PHYS 333	1	Elective(s) in physics	1
	2		**2**

Senior			
First Semester	**Credits**	**Second Semester**	**Credits**
PHYS 331		1 Elective(s) in physics	1
PHYS 317		1	
		2	**1**

Total Credits: 16

Bachelor of Science in Physics with a Concentration in Astrophysics

To complete a **Bachelor of Science major in physics with a concentration in astrophysics**, the PHYS 235 requirement is replaced with an ASTR 201 requirement and one of the 300-level electives must be ASTR 301.

In addition to the required coursework, students pursuing a concentration in astrophysics will be advised to participate in one or more on-campus or off-campus research experiences in astronomy or astrophysics. Such opportunities are frequently offered by department faculty as well as through a number of research programs for undergraduates that are hosted at observatories, research institutes and other universities across the country.

Additional Notes

A physics major leading to the bachelor of arts degree also is available in combination with a bachelor of science in engineering in a five-year program.

Courses in all of our degree programs are designed to provide students with many opportunities to practice and develop their writing, speaking, and information literacy skills, consistent with the learning objectives of the College of Arts & Science Core Curriculum (CASCC).

Students in our department also satisfy the Culminating Experience component of the College of Arts & Science Core Curriculum (CASCC) by taking PHYS 310 Experimental Physics, a required course for both B.S. and B.A. majors, in the spring of either their junior or senior year. In this course students perform substantial multi-week experiments that explore concepts that they have learned throughout the major, including classical mechanics, wave phenomena, electricity and magnetism, quantum physics, thermodynamics, computer simulation and astronomy. This course also stresses other learning objectives through writing of research papers and weekly oral presentations.

Honors in physics is given to those students who are accepted by the University Honors Council and successfully complete and defend an honors thesis in physics.

Study abroad is possible for students completing either a bachelor of arts or bachelor of science degree. Such study should be discussed well in advance with the academic adviser and the chair of the Department of Physics & Astronomy.

Students wishing to become certified as secondary school physics teachers should consult with the Department of Education and the chair of the Department of Physics & Astronomy to arrange a plan of study that ensures that all of the requirements for certification will be met.

Bachelor of Science in Biophysics

A **Bachelor of Science major** in biophysics consists of a total of 14 courses with the following list of 11 required courses:

PHYS 211	Classical and Modern Physics I	1
PHYS 212	Classical and Modern Physics II	1
BIOL 203	Integrated Concepts in Biology Fall	1
BIOL 204	Integrated Concepts in Biology Spring	1
CHEM 205	Principles of Chemistry	1
or CHEM 207	Explorations in Chemistry	
CHEM 211	Organic Chemistry I	1
MATH 211	Calculus III [1]	1
PHYS 222	Wave Mechanics and Quantum Physics	1
PHYS 315	Experimental Biophysics	1
PHYS 317	Thermodynamics and Statistical Mechanics	1
PHYS 340	Biophysics	1
And three advanced electives from the following list of courses, with at least one elective from BIOL, and up to one credit-bearing research with faculty: [2]		3
Advanced electives in Physics:		
PHYS 303	Modern Optics	
PHYS 331	Advanced Classical Mechanics [3]	
PHYS 332	Quantum Mechanics	
PHYS 333	Electromagnetic Theory I	

PHYS 334	Electromagnetic Theory II [3]
PHYS 338	Computer Simulations in Physics
PHYS 339	Advanced Quantum Mechanics and Particle Physics [3]
Advanced electives in Biology:	
BIOL 302	Microbiology
BIOL 306	Biology of Host-Microbe Interactions
BIOL 312	Comparative Vertebrate Anatomy
BIOL 313	Mammalogy
BIOL 318	Principles of Physiology
BIOL 327	Molecular Biology
BIOL 328	Endocrinology
BIOL 331	Genomics
BIOL 339	Developmental Biology
BIOL 340	Biochemical Methods
BIOL 347	Virology
BIOL 352	Cell Biology
BIOL 362	Topics in Cell Biology
BIOL 365	Introduction to Microscopy
Advanced electives in Chemistry: [4]	
CHEM 341	Physical Chemistry I
CHEM 347	Special Topics in Physical Chemistry
CHEM 351	Biochemistry I
CHEM 358	Biochemical Methods

1 MATH 211 is a required major-related course.
2 For the three 300-level electives, students who complete BIOL 201 are not required to choose a BIOL course as one of these three electives.
3 These courses include a prerequisite that is not part of the core curriculum for biophysics.
4 Students who are interested in a more chemistry-focused direction can pursue this path by taking CHEM 212 and CHEM 231.

Recommended course sequences are available at www.eg.bucknell.edu/physics/biophysics/ (http://www.eg.bucknell.edu/physics/biophysics/).

Courses in the biophysics degree program are designed to provide students with many opportunities to practice and develop their writing, speaking and information literacy skills, consistent with the learning objectives of the College of Arts & Science Core Curriculum (CASCC).

Students majoring in biophysics also satisfy the Culminating Experience component of the College of Arts & Sciences Core Curriculum (CASCC) by taking the combination of PHYS 315 Experimental Biophysics and PHYS 340 Biophysics. PHYS 315 Experimental Biophysics is a W-2 course within the major and provides a suite of project-based modules to hone in experimental skills in probing biological systems. In addition, students will write research-style papers, work in teams and present the research outcomes in this course. Complementary to the experimental aspects, PHYS 340 is a theory-based course that studies the physics of cellular structures and processes, with emphasis on mechanics and thermodynamics of biological systems.

Study abroad is possible for students majoring in biophysics. Students are strongly encouraged to plan such study so that they can complete their culminating experience in time. It is also advised that students discuss their plan to study abroad well in advance with the academic adviser and the chair of the Department of Physics & Astronomy.

Minor in Physics

A **minor** in physics consists of four 200 or 300-level physics courses, which may include ASTR 201. Advanced placement credit does not count toward the minor.

Majors in Physics (B.A. and B.S.) and Biophysics (B.S.) will:

- Be able to solve quantitative problems that require an understanding of the fundamental principles in each of the major areas of physics. Show a working knowledge of how a broad array of physical phenomena can be explained using these fundamental concepts.
- Exhibit a proficiency in the methods of scientific inquiry in laboratory and/or research projects.
- Use critical thinking skills to formulate and solve quantitative problems.
- Present well-organized, logical and scientifically sound oral and written scientific reports.
- Understand the variety of career paths and opportunities that are open to students who have majored in physics and/or astronomy.

Non-majors in Physics (meeting laboratory science requirements) will:

- Demonstrate an understanding of fundamental concepts in a field of physics and/or astronomy.
- Develop an appreciation for the methods of scientific inquiry through laboratory experiences.
- Demonstrate the critical thinking and problem solving skills required in scientific disciplines.

Astronomy Courses

ASTR 101. Our Solar System. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:3
An introduction to astronomy concentrating on our evolving understanding of the solar system. Designed for non-science majors. No prerequisite.

ASTR 102. Stars, Galaxies, and Beyond. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:3
An introduction to astronomy concentrating on the structure of our universe beyond the solar system. Designed for non-science majors. ASTR 101 is not a prerequisite for ASTR 102.

ASTR 201. Observational Astrophysics. 1 Credit.
Offered Alternate Fall or Spring; Lecture hours:2,Other:2
This course covers spherical astronomy and observational techniques, and applications of physics to solar system objects, stars, stellar evolution, galaxies, and cosmology. Some night observing required. Laboratories focus on observational techniques and data reduction. Prerequisite: PHYS 212 or PHYS 212E.

ASTR 301. Astrophysics. 1 Credit.
Offered Alternating Spring Semester; Lecture hours:3
An introduction to general astrophysics covering mechanics of orbiting bodies, radiation laws, stellar spectra, stellar atmospheres, the internal constitution of stars, stellar energy, galaxies and cosmology. Prerequisites: PHYS 222 and MATH 202, or permission of the instructor. Crosslisted as PHYS 301.

ASTR 337. Independent Study in Astronomy/Astrophysics. .5-1 Credits.
Offered Both Fall and Spring,Topics course; Lecture hours:Varies,Other:Varies; Repeatable
Seminar or independent study in areas of current interest in the astronomy/astrophysics community. Prerequisite: permission of the instructor.

ASTR 338. Contemporary Study in Astronomy/Astrophysics. 1 Credit.
Offered Either Fall or Spring,Topics course; Lecture hours:3
Seminar in topics of current interest in the astronomy and astrophysics community. Co- and prerequisites are dependent on topic and instructor. Prerequisite: permission of the instructor.

ASTR 350. Undergraduate Research. .5-1 Credits.
Offered Both Fall and Spring,Topics course; Lecture hours:Varies,Other:Varies; Repeatable
Undergraduate research in astronomy/astrophysics. Prerequisite: permission of the instructor.

Physics Courses

PHYS 140. Physics for Future Leaders. 1 Credit.
Offered Occasionally; Lecture hours:3,Other:3
The science behind key issues facing us as engaged citizens and future leaders. Topics include energy, climate change, space travel, and technology, as well as the processes that lead to scientific progress. Designed for non-science majors. No prerequisites. Not open to students who have completed a 200-level physics course.

PHYS 141. Secrets of the Universe. 1 Credit.
Offered Occasionally; Lecture hours:3,Other:3
The great ideas of 20th-century physics (symmetry principles, relativity, and quantum mechanics) and their application to cosmology and the evolution of the universe. Also, historical development and philosophical implications of these ideas. Designed for non-science majors. No prerequisite. Not open to students who have successfully completed a 200-level physics course.

PHYS 142. Light and Vision. 1 Credit.
Offered Occasionally; Lecture hours:3,Other:3
Particle and wave theories of light, cameras and optical instruments, the visual process, lasers, and optical communications. Designed for non-science majors. No prerequisite. Not open to students who have successfully completed a 200-level physics course.

PHYS 143. The Physics of Time and Time-Keeping. 1 Credit.
Offered Either Fall or Spring; Lecture hours:1,Other:3
Timekeeping from astronomical to mechanical to atomic, time in physics from classical to relativistic to quantum, the physics of time from irreversibility to simultaneity to singularity. Designed for nonscience majors. No prerequisites. Not open to students who have successfully completed a 200-level physics course.

PHYS 144. How Things Work. 1 Credit.
Offered Occasionally; Lecture hours:3,Other:3
This course introduces the ideas of physics in the context of everyday phenomena, including common inventions and topics in medicine, sports, and music. Designed for non-science majors. No prerequisite. Not open to students who have successfully completed a 200-level physics course.

PHYS 146. Science and Technology in War and Peace. 1 Credit.
Offered Occasionally; Lecture hours:3
The tug of war between human frailties and yearning for peace has generated a plethora of scientific discoveries and technological innovations: electro-magnetism, wireless communications, lasers, the Internet, hypersonic missiles, and nuclear reactions. Designed for non-science majors. No prerequisites. Not open to students who have successfully completed a 200-level physics course.

PHYS 147. Energy and Sustainability. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Other:3
Examination of energy, its transformations, its effects on resource depletion, and environmental degradation. Models of sustainability for transportation, architecture, waste management, and personal lifestyle choices. Designed for non-science majors. No prerequisite. Not open to students who have successfully completed a 200-level physics course.

PHYS 211. Classical and Modern Physics I. 1 Credit.
Offered Fall Semester Only,TLC Tutoring Course; Lecture hours:2,Other:5
The first course in a two-course sequence that surveys major areas of physics. Topics include Newtonian mechanics, relativity, thermodynamics and statistical mechanics, and gravity. Corequisite: MATH 201.

PHYS 212. Classical and Modern Physics II. 1 Credit.
TLC Tutoring Course,Offered Spring Semester Only; Lecture hours:2,Other:5
The second course in a two-course sequence that surveys major areas of physics. Topics include electricity and magnetism, light and waves, quantum mechanics, and particle physics. Prerequisites: PHYS 211 and MATH 201, or permission of the instructor.

PHYS 221. Classical Mechanics. 1 Credit.
Offered Fall Semester Only; Lecture hours:3,Lab:3
Newtonian mechanics including conservation laws, rotational dynamics, forced damped harmonic motion, and coupled oscillations. Prerequisites: PHYS 211 and MATH 202.

PHYS 222. Wave Mechanics and Quantum Physics. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Other:2
Physics of coupled oscillations and waves, including classical wave equation. Wave-particle duality; origin and elementary applications of quantum mechanics; the Schroedinger wave equation; atomic and nuclear physics. Prerequisites: PHYS 212P with a minimum grade of D or PHYS 212E with a minimum grade of D.

PHYS 235. Applied Electronics. 1 Credit.
Offered Spring Semester Only; Lecture hours:2,Lab:4
Circuit fundamentals, linear and digital integrated circuits, transducers, analog to digital conversion, filtering, Fourier methods, microcomputers, and computer interfacing. Designed for science and computer science majors. Prerequisite: PHYS 212 (or PHYS 212E). Open to electrical engineering students by permission only.

PHYS 301. Astrophysics. 1 Credit.
Offered Alternating Spring Semester; Lecture hours:3
An introduction to general astrophysics covering mechanics of orbiting bodies, radiation laws, stellar spectra, stellar atmospheres, the internal constitution of stars, stellar energy, galaxies and cosmology. Prerequisites: PHYS 222 and MATH 202, or permission of the instructor. Crosslisted as ASTR 301.

PHYS 303. Modern Optics. 1 Credit.
Offered Occasionally; Lecture hours:3
Geometrical optics, interference and diffraction, and topics such as: quantum optics, optical properties of matter, lasers and holography. Prerequisite: PHYS 222 or permission of the instructor.

PHYS 310. Experimental Physics. 1 Credit.
Offered Spring Semester Only; Lecture hours:1,Other:5
Methods and techniques used in experimental and computational physics, including data analysis and numerical methods, use of standard research equipment, and documentation of laboratory work emphasizing written and oral communication of scientific results. Prerequisite: PHYS 222 or permission of the instructor.

PHYS 315. Experimental Biophysics. 1 Credit.
Offered Alternating Fall Semester; Lecture hours:1,Other:5
Methods and techniques used in experimental and computational biophysics, including optical tweezers, microscopy, computational methods, use of standard research equipment, and documentation of laboratory work emphasizing written and oral communication of scientific results. Juniors and seniors majoring in Biophysics only. Not open to first-year or sophomore students. Biophysics major only.

PHYS 317. Thermodynamics and Statistical Mechanics. 1 Credit.
Offered Fall Semester Only; Lecture hours:3
The laws of thermodynamics, thermodynamic functions, kinetic theory of gases, statistical mechanics. Prerequisites: PHYS 212 (or PHYS 212E) and either PHYS 221 or PHYS 222, or permission of the instructor.

PHYS 331. Advanced Classical Mechanics. 1 Credit.
Offered Fall Semester Only; Lecture hours:3
Kinematics and dynamics of particles, systems, and rigid bodies. Hamilton's principles, Lagrange's equations, theory of small vibrations, orbital mechanics, accelerated frames, and nonlinear dynamics. Prerequisites: PHYS 221.

PHYS 332. Quantum Mechanics. 1 Credit.
Offered Fall Semester Only; Lecture hours:3
Basic postulates and applications, perturbation theory, angular momentum, scattering theory, relativistic effects. Prerequisites: PHYS 222 and MATH 211, or permission of the instructor.

PHYS 333. Electromagnetic Theory I. 1 Credit.
Offered Fall Semester Only; Lecture hours:3
Classical electromagnetic theory, including scalar and vector potentials, electrostatics, magnetostatics, time-dependent fields, and culminating with Maxwell's equations. Prerequisites: PHYS 212 (or PHYS 212E) and MATH 211. Juniors and seniors only, except by permission.

PHYS 334. Electromagnetic Theory II. 1 Credit.
Offered Alternating Spring Semester; Lecture hours:3
Continuation of PHYS 333. Electromagnetic waves, radiation theory, theory of relativity, and elements of plasma physics. Prerequisite: PHYS 333.

PHYS 336. Mathematical Methods in Physics. 1 Credit.
Offered Occasionally; Lecture hours:3
Topics will include two or three of the following: complex variables, special functions, tensor analysis, group theory, partial differential equations. Prerequisites: PHYS 221 and PHYS 222, MATH 212 and MATH 245, or permission of the instructor. Crosslisted as PHYS 636.

PHYS 337. Independent Study in Physics. .5-1 Credits.
Offered Either Fall or Spring,Topics course; Lecture hours:Varies; Repeatable
Independent study in areas of current interest in the physics and astronomy community. Prerequisites: permission of the department and permission of the instructor.

PHYS 338. Computer Simulations in Physics. 1 Credit.
Offered Occasionally; Lecture hours:3; Repeatable
Introduction to the use of numerical simulations in physics. Students learn through frequent programming exercises in computer labs, and via a semester long project. The course includes scientific literature searches, data analysis, and scientific oral and written presentations. Prerequisite: PHYS 221.

PHYS 339. Advanced Quantum Mechanics and Particle Physics. 1 Credit.
Offered Alternating Spring Semester; Lecture hours:3
Advanced topics in quantum mechanics including applications to elementary particle physics. Prerequisite: PHYS 332, or permission of instructor.

PHYS 340. Biophysics. 1 Credit.
Offered Alternating Spring Semester; Lecture hours:3
Physics of cellular structures and processes, with emphasis on mechanics and thermodynamics. Juniors and seniors only. Prerequisite: PHYS 212 or PHYS 212E and either PHYS 221 or PHYS 222 or permission of the instructor.

PHYS 350. Undergraduate Research. .5-1 Credits.
Offered Either Fall or Spring,Topics course; Lecture hours:Varies; Repeatable
Undergraduate research. Prerequisite: permission of the instructor.

PHYS 3NT. Physics Non-traditional Study. 1-4 Credits.
Offered Fall, Spring, Summer,Topics course; Lecture hours:Varies,Other:4
Non-traditional study in Physics.